States
nent of
ure

Economic
Research
Service

Agriculture
and Trade
Analysis
Division

Efficiency and Growth in Agriculture

A Comparative Study of the Soviet Union, United States, Canada, and Finland

Robert B. Koopman

It's Easy To Order Another Copy!

Just dial 1-800-999-6779. Toll free.

Ask for *Efficiency and Growth in Agriculture: A Comparative Study of the Soviet Union, United States, Canada, and Finland* (AGES 89-54).

The cost is $5.50 per copy. For non-U.S. addresses, add 25 percent (includes Canada). Charge your purchase to your VISA or MasterCard, or we can bill you. Or send a check or purchase order (made payable to ERS-NASS) to:

ERS-NASS
P.O. Box 1608
Rockville, MD 20849-1608.

We'll fill your order by first-class mail.

Efficiency and Growth in Agriculture: A Comparative Study of the Soviet Union, United States, Canada, and Finland. By Robert B. Koopman. Agriculture and Trade Analysis Division, Economic Research Service, U.S. Department of Agriculture. Staff Report No. AGES 89-54.

Abstract

Growth in the agricultural sector of the Soviet Union has been slow and a constant cause of concern for the Soviet leadership. Western economists have long argued that the Soviet system lacks the efficiency in production that market forces provide in the West. This study finds little empirical evidence to support the argument of low levels of static allocative or technical efficiency in Soviet-type economies, compared with the West. Instead, the study shows that the slow pace of technological innovation is the main reason for slow Soviet growth.

Keywords: Soviet Union, Canada, Finland, United States, agriculture, efficiency, stochastic frontiers, technological change

1301 New York Avenue, NW.
Washington, DC 20005-4788

October 1989

Contents

Efficiency and Growth in Agriculture

A Comparative Study of the Soviet Union, United States, Canada, and Finland

Robert B. Koopman

Introduction

This paper looks at the static technical efficiency of agricultural production in the Soviet Union compared with that of the United States, Canada, and Finland. The main contributions of this paper are empirical estimates of the regional static technical efficiency of Soviet agriculture and the relative technical efficiency of Soviet agriculture compared with a sample of 10 U.S. States, 4 Canadian Provinces, and Finland. The results on technical efficiency used in conjunction with findings of other studies on allocative efficiency suggest that the main efficiency differences between Soviet and western economies are not necessarily in how many resources it takes to produce output in any one year, or how well those resources are allocated across competing uses, but more likely due to the change in technology used over time.

Soviet agriculture has been characterized in recent years as being highly inefficient and a vast sinkhole for increasingly valuable resources. Output growth has been slow despite ever-increasing input use. The generally accepted argument is that the managerial bonus system, wage payment system, irrational prices, poor investment decision criteria, lack of incentives to innovate and introduce new technology, and planners' interference with economic agents' decisionmaking all lead to technical and allocative inefficiency, both statically and dynamically (see Gregory and Stuart, pp.338-50).

Western agriculture, on the other hand, has been characterized as highly efficient, producing ever more output but with minimal increases in input use. The efficiency of western agriculture is often attributed to the competitive market environment that shakes out inefficient producers and allocates resources efficiently. Yet, even in the West, there is significant government intervention in agriculture, as governments support prices, subsidize inputs, undertake massive irrigation projects, control acreage, provide low-cost credit, and control trade in many important commodities.[1] Despite extensive government

---

[1]A number of trade liberalization studies have recently documented the extent of government intervention in many western countries within the framework of the General Agreement on Tariffs and Trade in the Uruguay Round. Measuring the value to agricultural producers and consumers of all government

intervention, western agriculture is still characterized as relatively efficient.

While the nature and extent of government intervention in both systems varies widely, it is much greater in Soviet-type systems. In most western economies, governments influence production and input decisions by farmers and other agricultural-related sectors through numerous policies, but leave final production and input decisions up to the farmer. The Soviet farmer traditionally has faced far more direct constraints by being told, in effect, what to produce, how much to produce, and what inputs to use. What is not clear is how these differences in economic environments manifest themselves in terms of economic efficiency. One would expect, given the higher degree of government intervention, that Soviet agriculture would suffer from higher levels of inefficiency. Yet, based on the results of this study, other studies looking at static allocative efficiency, and the theory of induced development put forth by Hayami and Ruttan, the evidence suggests that the main efficiency differences between the systems are more likely dynamic rather than static. Western agricultural policy environment is not necessarily more statically efficient than that of a Soviet system, but it appears to allow more innovation and technological change than does a Soviet system, and hence is more dynamically efficient.

First, brief arguments suggesting relatively high levels of technical inefficiency in the Soviet Union are presented. Then a summary of studies on allocative inefficiency in western and Soviet-type economic systems is presented. Then a model designed to measure the technical efficiency of the 15 Soviet republics using a data set constructed by the author is presented and estimated. To provide some a priori benchmark of technical efficiency, Soviet cost-of-production data are used to construct some rough efficiency groupings for comparison of the model's efficiency estimates. After constructing the efficiency rankings, output and input use patterns are investigated to identify characteristics associated with relatively efficient republics.

Third, a comparison is made between the Soviet efficiency estimates found in part two with other studies using similar models. A data set constructed by Karen Brooks (see Johnson and Brooks) is then used to make stronger statements regarding the comparative technical efficiency of Soviet and western agriculture. This second data set consists of climatic analogues to the Soviet Republics using 10 U.S. States, 4 Canadian

---

interventions has been emphasized. Recent studies by U.S. Department of Agriculture include Agriculture in the Uruguay Round: Analysis of Government Support, Staff Report No. AGES-880802; Government Intervention in Agriculture: Measurement, Evaluation, and Implications for Trade Negotiations, FAER-229; and Estimates of Producer and Consumer Subsidy Equivalents: Government Intervention in Agriculture, 1982-86, Staff Report No. AGES-880127.

Provinces, and Finland. Finally, using criteria from Hayami and Ruttan's theory of induced development in conjunction with the empirical findings of this and other studies on static efficiency, it is argued that the recent slow agricultural growth in the Soviet Union is more likely the result of a lack of dynamic efficiency than from low levels of static efficiency. The findings have significant implications for current and future agricultural policy in the Soviet Union, namely, that it may be more important to allow induced innovations to spur growth rather than depend on adjustments to the current system to increase static efficiency and growth.

Efficiency in the Soviet Economy

Many economists studying the Soviet Union argue that central planning results in both technical and allocative inefficiency. Technical inefficiency, defined as producing somewhere beneath the production possibilities frontier, supposedly results from a lack of bankruptcy discipline and from planners' interference in farms' day-to-day decisionmaking. Firms may continue to operate in the long run, despite inefficient input use in production because of state subsidization. Allocative inefficiency, defined as using the wrong mix of inputs to produce a given output level for given input prices, arises because central planners control input allocation schemes and because prices, at all levels, do not necessarily correspond to their shadow values. Under allocative inefficiency, firms are assumed to be producing on their production possibilities frontier, but in the wrong spot given input prices. Thus, the economy or sector as a whole is not operating on its production possibilities frontier.

Until recently, most studies on efficiency, for both Soviet-type and market-type economies, focused on allocative efficiency (see Barreto and Whitesell, Desai and Martin, Harberger, Koopman 1984, Shoven and Whalley, Thornton, Toda 1986, Whitesell, and Whalley). These studies assume technical efficiency and then attempt to measure either output losses or input waste due to the misallocation of resources. Two reasons for the focus on allocative instead of technical efficiency are the assumed disciplinary effects of bankruptcy in market-type economies (hence, technically inefficient firms cannot survive) and, more broadly, the need to rely on observed data. The need to rely on observed data means that the standard production or cost function estimation procedures implicitly assume that the observed output and input or cost and wage vectors lie on the production frontier and cost function. The existence of technical inefficiency means that the observed data do not lie on the surface of these functions and implies that losses measured in the above studies would understate the true economic losses to the economy.

The results of studies attempting to measure allocative efficiency seem to suggest that, given the estimated technology, allocative efficiency in Soviet-type economies is reasonably high

Table 1--Estimates of allocative efficiency

Country and author	Sector	Time period	Efficiency estimate
			Percent
USSR:			
Thornton	Industry	1960-64	96-97
Desai and Martin	Industry	1955-75	93.48
Koopman	Industry	1960-80	98.85
Barreto and Whitesell	Industry	1960-84	93.63
Toda (1986)	Industry	1958-81	92.21
Toda (1987)	Economywide	1960-84	86.82
USA:			
Barreto and Whitesell	Industry	1960-84	95.88
Hungary, Whitesell	Industry	1961-84	69.67
West Germany, Whitesell	Industry	1964-81	91.26
Poland, Kemme	Industry	1973-80	91.30

Note: Many studies on the allocative efficiency of taxes have been done for western countries, but those studies are not discussed here.

(table 1).[2] Most of these studies have focused on industrial sectors because of data deficiencies in other sectors. For the analysis in this study, we assume that the industry efficiency levels approximate the efficiency levels in other sectors. The only economy-wide study, Toda 1987, found that the efficiency level is somewhat lower than that found in other studies, but efficiency levels by sector are not reported. Therefore, it is not clear if Toda's results imply lower efficiency in non-industrial sectors, or if efficiency in all sectors is found to be lower.

---

[2]The assumption of "given the estimated technology" is critically important. In most empirical studies, this one included, efficiency is measured based on the technology we observe, or estimate, from available data. An opportunity cost concept of efficiency loss, where one would ask what the efficiency level would be if the best available, though not necessarily used, potential technology was used. That is, the technology we observe may not be the best, or even the one desired and, hence, the technology choice itself is costing the economy in terms of efficiency. Further when efficiency gains from resource reallocation are considered, no change in technology from one sector to another is allowed, when in reality one may want to change the technology as well as reallocate the resources.

The estimates of allocative efficiency do not provide conclusive evidence of higher allocative efficiency in western-type economies than in Soviet-type economies, yet there has been a definite difference in growth and perceived efficiency between East and West over the past 20 years. The growth differential has reached the point where most Soviet-type economies, even the Soviet Union under General Secretary Gorbachev, have recognized the need for changes in their economic mechanisms.

Since studies focusing on allocative efficiency have not fully explained this growth differential, this paper looks at technical efficiency for further insight. This study attempts to measure the technical efficiency of Soviet agriculture in isolation as well as in a comparative setting. The results suggest that one may have to look elsewhere for the sources of slow growth in Soviet agriculture, perhaps to a measure of dynamic efficiency that over time accounts for different rates of technological change.

Measurement of Technical Efficiency in Soviet Agriculture

To measure technical efficiency, this study applies a technique that attempts to measure inefficiency based on observed data and estimates of an economy's production frontier. The technique, stochastic frontier estimation, essentially assumes that skewness in the observed ordinary least squares (OLS) or generalized least squares (GLS) residuals is an indicator of technical inefficiency and attempts to separate the residuals into two components: a symmetric, random error term and a one-sided, technical inefficiency error term.

We apply the methodology to two data sets, one collected only for the 15 Soviet republics using official Soviet statistics, and the second a comparative data set that includes the 15 Soviet republics as well as 10 U.S. States, 4 Canadian Provinces, and Finland. The two data sets were collected independently of each other, the first by the author, and the second by Karen McConnell Brooks.[3] The use of two independently collected data sets enables one to consider the robustness of the technical efficiency estimates for the Soviet Union as well as to make comparative statements about Soviet technical efficiency versus the efficiency of the sampled western regions.

Stochastic Frontiers

Danilin and others were the first to test the hypothesis of technical efficiency in the Soviet Union using stochastic

---

[3]The data are from Johnson and Brooks and are described on pages 129-44.

frontier methodology. They state, "western theories of Soviet economic behavior, particularly the command economy hypothesis, suggest that Soviet enterprises will be both technologically and economically inefficient" (Danilin and others, p. 226). It has been widely accepted by western economists, and recently by more and more Soviet economists, that the managerial bonus system, the wage payment system, irrational prices, poor investment decision criteria, lack of incentives to innovate and introduce new technology, and planners' interference with economic agents' decisionmaking all lead to technical and allocative inefficiency, both statically and dynamically.

To test the claim of technological inefficiency compared with existing best practice, Danilin and others used stochastic frontier estimation. This model tests for statistically significant shortfalls in actual production from the maximum possible production, given the core production function and random noise.

The frontier can be expressed as

$$Y_{it} = f[X_{it}, \beta] + v_{it} - u_{it}$$

where,

Y is the vector of observed outputs
X is the vector of observed inputs
β is the vector of structural parameters
i is the number of firms or observational units
t is the number of time periods
$v \sim N(O, \sigma_v^2)$
$u \sim N(O, \sigma_u^2)$ truncated to be positive[4]

While Y, X, and β are self-explanatory, the error-term structure deserves further explanation. The error term v is the usual assumed error term with zero mean and constant variance. The v represents the random influence of measurement errors, exogenous shocks, and differences in operating environments. The error term u represents any systematic error influences that cause firms to produce below the production frontier. In this study, u is assumed to be a half-normal variable truncated to be non-negative, independent of v, and uncorrelated with X.[5] The error term u essentially reflects skewness in the production function error and attributes it to inefficiency. This assumption may be debatable but can be further explored by observing the constancy of skewness over time. Constancy over time lends some credence to this assumption (see Schmidt and Sickles). A good explanation of this specification is found in Aigner, Lovell, and Schmidt:

---

[4]Other distributions commonly chosen are the exponential and the gamma.

[5]See Schmidt and Sickles for discussion on the problem of correlation with independent variables.

> The economic logic behind this specification is that the process is subject to two economically distinguishable random disturbances, with different characteristics. ...from a practical standpoint, such a distinction facilitates the estimation and interpretation of a frontier. The nonpositive disturbance u_i reflects the fact that each firm's output must lie on or below its frontier $[f(X_{ij}\beta) + v_i]$. Any such deviation is the result of factors under the firms control, such as technical and economic efficiency, the will and effort of the producer and his employees, and perhaps such factors as defective and damaged product. But, the frontier itself can vary randomly across firms, or over time for the same firm. On this interpretation, the frontier is stochastic, with random disturbance $v_i = 0$ being the result of favorable as well as unfavorable external events such as luck, climate, topography, and machine performance. Errors in observation on Y constitute another source of $v_i = 0$ (pp. 24-5).

As initially applied in this study, the stochastic core production function $[f(X_{it}, \beta) + v_{it}]$ can vary randomly across the 15 republics (later 15 regions from outside the USSR will be added), with the v_i accounting for regional differences such as luck, climate, and topography. The u_i, on the other hand, accounts for any differences among regions that result from factors the regions should be able to control. So one assumes that regional differences in the "will and effort" of farms and employees, and their effectiveness at translating inputs into output are captured by u_i, thus measuring differences in regional technical efficiency.

While stochastic frontier methodology explicitly models technical efficiency across production units, it can do so only in a relative sense. Since the approach uses observed data, it is only capable of identifying areas of best practice and the relative position of other areas against the best practice area. The true underlying production frontier, or the one determined by engineering data may not be captured in the observed data. Thus when referring to the "frontier" in this study, one really means best observed practice. All efficiency measures are also expressed relative to this best practice result.

An important assumption made in this study is that all the republics have the same core production function, though subject to individual stochastic shocks. Should the Russian Republic have a production function intrinsically different from Uzbekistan's, then the current model is misspecified and is not necessarily capturing differences in technical efficiency. One may be comforted, however, by the fact that a single production function for cross-section studies of agriculture is not an uncommon assumption despite significant regional differences in output mix and topological conditions.

Model Results and Efficiency Estimation

A translog functional form with Hicks neutral technical change was assumed to represent the technology of Soviet agriculture. A Cobb-Douglas version was also estimated for comparison purposes, mainly because much of the previous work relating to Soviet agriculture has relied on this restrictive, though useful, functional form. Only the translog results will be discussed in detail here as the choice of functional form has no significant effect on the general categorization of efficient versus inefficient regions.

The model was estimated using the LIMDEP frontier estimator.[6] Initially OLS was run to test for autocorrelation and heteroskedasticity. Autocorrelation was found and the data were transformed by a ρ estimated from the OLS residuals to correct for it. The frontier estimation used the corrected data. All runs are estimated using logged explanatory variables differenced about the mean, so the parameter estimates are the elasticities at the mean.

The parameter estimates from the frontier estimation, reported in table 2, appear reasonable. The point estimates for labor and land are nearly equal, significantly greater than zero, and are the largest elasticities at the means. The fertilizer elasticity is only half as great as the labor and land estimates and is also significantly greater than zero. Neither the livestock nor capital estimates are significantly greater than zero, though both likely contribute to production in a significantly positive way. Problems with possible collinearity or poor measurement, particularly with the capital proxy, are the likely culprits. The estimated rate of technological change is predictably low, and not significantly different from zero. Many of the square and cross-product terms are significantly different from zero, suggesting some nonconvexities in the isoquants and providing some justification for using the more flexible translog functional form over the Cobb-Douglas.

The two parameter estimates of more immediate interest to us are $\hat{\lambda}$ and $\hat{\sigma}$. The $\hat{\lambda}$ is the ratio of the estimated standard errors of the two error components (v - u). So,

$$\hat{\lambda} = \frac{\hat{\sigma}_u}{\hat{\sigma}_v}$$

The estimate of λ suggests that the standard error of the regression due to the one-sided component is 1.75 times greater than that of the random component. This estimate suggests that most of the variation in output is due to technical inefficiency, with the smaller amount due to completely random events.

---

[6] A discussion of the LIMDEP frontier estimator is found in Greene 1986, LIMDEP, User's Manual, ch. 20, p. 6.

Table 2--Translog production function estimation results for the Soviet Union using stochastic frontier methodology

Variable	$\hat{\beta}$	t-statistic
One	0.112	3.21
Year	.002	.67
Fertilizer	.225	2.35
Livestock	.043	.29
Machinery	.037	-.27
Land	.458	2.65
Labor	.450	6.50
Fertilizer squared	.0912	.65
Machinery squared	.242	2.42
Land squared	.542	4.75
Labor squared	.153	2.68
Livestock squared	.007	.05
Fertilizer*machinery	-.416	-3.84
Fertilizer*land	.418	3.63
Fertilizer*labor	.157	3.20
Fertilizer*livestock	.067	.71
Machinery*land	-.718	-3.83
Machinery*labor	-.002	-.04
Machinery*livestock	.323	2.35
Land*livestock	-.378	-1.69
Land*labor	-.259	-2.89
Livestock*labor	.129	.88
Lambda	1.749	2.15
Sigma	.098	8.17

Statistics from GLS regressions:

n = 225
R^2adj = .987
DW = 1.71
F = 187.36

One can use $\hat{\sigma}$, the estimated standard error of the regression, and $\hat{\lambda}$ to calculate estimates of σ_u and σ_v, since $\hat{\sigma}^2 = \hat{\sigma}^2_u + \hat{\sigma}^2_v$, and

$$\hat{\sigma}_u = \hat{\lambda} * \hat{\sigma}_v$$

$$\hat{\sigma}^2_u = \hat{\lambda}^2 * \hat{\sigma}^2_v$$

thus $\hat{\lambda}^2 = 3.06$, $\hat{\sigma}^2_v = .00237$, and $\hat{\sigma}^2_u = .00725$.

In addition, $\hat{\sigma}_u$ can be used to estimate the mean level of technical inefficiency for the sample since,

$$\hat{\mu} = \sigma_u\sqrt{(2/\pi)},$$

for the half-normal case (see Jondrow and others). Thus, $\hat{\mu}$ = .0679, which says that, on average, Soviet gross agricultural output is 6.7 percent less than what could be attained if all republics operated on the frontier and encountered only stochastic shocks in production.

Furthermore, the findings of Jondrow and others allow us to estimate values for the inefficiency error term u by observation. One can then identify republics that are relatively efficient, and in which years the greatest inefficiencies occurred. These estimates of u are conditional upon the estimates of e, where e = (v - u), the regression's full residuals. Jondrow and others show that the conditional distribution of u given e is that of a $N(\mu_*, \sigma^2_*)$ variable truncated at zero (see Jondrow and others, p. 234), where,

$$\sigma^2 = \sigma_u^2 + \sigma_v^2,$$

and,

$$\mu_* = -\sigma_u^2 \, e/\sigma^2,$$

and,

$$\sigma_*^2 = \sigma_u^2 \, \sigma_v^2/\sigma^2$$

where σ^2, σ_u^2, σ_v^2 are the variance of the regression estimate, the variance of the one-sided error component, and the variance of the two-sided error component. The e is the regression residual, and μ_* and σ_*^2 are the mean and variance of the conditional distribution of u given e. From this, Jondrow and others obtain,

$$E(u|e) = \sigma_*\left[\frac{f(e\lambda/\sigma)}{1 - F(e\lambda/\sigma)} - \frac{e\lambda}{\sigma}\right]$$

where f and F represent the standard normal density and cumulative density functions. This is the expression for the value of u for any given e. Using this expression, one can estimate u, the percent beneath the production frontier for each observation across all 15 republics. One can then average these over the 15 years sampled and rank the republics by average efficiency over the sample period. The most efficient republics will have the smallest u, and the least efficient will have the largest. The transformation z = exp generates maximum likelihood estimates of technical efficiency for each observation (see Danilin and others).

Cost of Production Efficiency Rankings

Before proceeding to the model's efficiency estimates, we construct rankings of technical efficiency using Soviet sebestoimost', or prime cost of production, data to provide some <u>a priori</u> expectations about each republic's relative efficiency. If we assume that the low cost of production relative to the mean is an indicator of technical efficiency, then the cost data provided in tables 3 and 4 suggest a breakdown of efficient versus inefficient republics as in table 5.

According to the sebestoimost' data the western republics (the Ukraine, Lithuania, Latvia, and Estonia) are relatively efficient as their average costs for most commodities, particularly those commodities accounting for a large share of their gross agricultural production, are less than the sample means. Kirgizia is the only central Asian republic ranked as efficient,and Belorussia lies in the middle, with half its commodity production costs greater and half less than the sample

Table 3--Soviet sebestoimost' data for major commodities on collective farms by republic, 1975

Republic	Grain	Cotton	Sugar-beets	Oil-seeds	Potatoes	Vegetables
			Rubles per ton			
USSR average	69	433	29	69	80	111
Armenia	90	-	41	-	139	98
Azerbaidzhan	85	502	-	-	204	195
Belorussia	91	-	41	-	64	86
Estonia	89	-	-	-	60	68
Georgia	85	-	34	119	137	182
Kazakhstan	86	348	31	77	159	128
Kirgizia	68	340	24	-	112	101
Latvia	114	-	39	-	97	90
Lithuania	95	-	38	-	82	100
Moldavia	56	-	25	73	212	132
Russian Republic	74	-	35	73	77	116
Tadzhikistan	157	456	-	-	154	91
Turkmenistan	144	474	-	-	214	134
Ukraine	53	-	26	64	97	105
Uzbekistan	180	413	-	-	204	87

	Cows	Swine	Goats	Milk	Eggs	Wool
			Rubles per ton			
USSR average	1,574	1,487	1,053	217	74	5,311
Armenia	1,788	2,035	1,309	266	110	5,337
Azerbaidzhan	1,786	1,502	998	273	132	4,822
Belorussia	1,564	1,758	1,619	202	69	7,691
Estonia	1,212	1,084	1,837	193	51	9,156
Georgia	2,458	2,136	1,217	318	100	5,589
Kazakhstan	1,667	1,661	865	249	104	4,890
Kirgizia	1,372	1,251	901	229	73	4,927
Latvia	1,439	1,346	1,801	210	59	9,782
Lithuania	1,468	1,486	1,790	203	59	8,483
Moldavia	1,774	1,303	1,365	222	97	6,056
Russian Republic	1,593	1,547	1,102	228	79	5,670
Tadzhikistan	1,958	1,844	1,142	294	127	4,574
Turkmenistan	1,756	1,820	857	271	98	3,087
Ukraine	1,529	1,399	1,216	199	67	5,537
Uzbekistan	1,779	1,812	1,256	251	119	3,763

- Little or no production in this republic.
Source: Narodnoe khozyaistvo v 1975, p. 417.

means. All of the remaining republics are ranked as relatively inefficient.

Note, however, that Soviet sebestoimost' is an incomplete measure of the true costs of production as it excludes land rents and returns to capital. Also, sebestoimost' is calculated using artificial Soviet prices that do not necessarily reflect scarcity values. These two deficiencies prevent definitive statements about relative efficiency based on sebestoimost' comparisons. The comparisons are drawn here for perspective only.

Table 4--Soviet sebestoimost' data, for major commodities on state farms by republic, 1975

Republic	Grain	Cotton	Sugar-Beets	Oil-Seeds	Potatoes	Vegetables
			Rubles per ton			
USSR average	944	39	40	-	93	98
Armenia	99	-	45	-	143	104
Azerbaidzhan	80	458	-	-	226	126
Belorussia	101	-	44	-	69	75
Estonia	96	-	-	-	65	64
Georgia	101	-	37	-	157	149
Kazakhstan	130	352	42	-	196	143
Kirgizia	75	438	26	-	136	108
Latvia	118	-	48	-	96	72
Lithuania	105	-	46	-	89	95
Moldavia	59	-	27	-	280	135
Russian Republic	91	-	47	-	92	90
Tadzhikistan	130	453	-	-	133	109
Turkmenistan	122	483	-	-	637	166
Ukraine	51	-	27	-	129	94
Uzbekistan	201	447	-	-	204	98

Republic	Cows	Swine	Goats	Milk	Eggs	Wool
			Rubles per ton			
USSR average	1,842	1,489	1,048	247	60	5,373
Armenia	1,825	2,093	1,400	260	73	5,270
Azerbaidzhan	2,077	1,861	1,105	292	90	4,241
Belorussia	1,665	1,741	2,035	218	46	9,455
Estonia	1,240	1,040	1,519	184	43	9866
Georgia	2,247	2,000	1,153	280	82	5,581
Kazakhstan	2,180	1,750	980	271	55	5,245
Kirgizia	1,702	1,396	1,065	260	53	5,448
Latvia	1,443	1,270	1,792	202	59	10,990
Lithuania	1,587	1,595	2,277	215	55	15,144
Moldavia	1,928	1,528	1,323	216	71	6,137
Russian Republic	1,853	1,488	1,115	258	60	5,806
Tadzhikistan	2,001	1,740	1,125	300	71	4,144
Turkmenistan	2,218	1,640	883	293	85	2,765
Ukraine	1,584	1,313	1,045	202	61	4,915
Uzbekistan	2,229	1,718	1,094	288	87	3,464

- Little or no production in this republic.
Source: Narodnoe khozyaistvo v 1975, p. 417.

Model Efficiency Rankings

The efficiency estimates from the frontier model rank the Baltic Republics as the most technically efficient, the Russian Republic (RSFSR) is ranked surprisingly high relative to the sebestoimost' ranking, the Transcaucasian Republics are average, and finally the central Asian Republics are relatively technically inefficient. Table 6 ranks the republics from relatively most efficient to least efficient, lists the expected value of u given e, and also lists the estimated technical efficiency. The results appear plausible given the sebestoimost' rankings. The author expected high rankings for the Baltic Republics and low rankings for Kazakhstan and the RSFSR.

Table 5--Relative efficiency ranking by Soviet republic sebestoimost' data[1]

Relatively efficient	Mixed	Relatively inefficient
Estonia	Belorussia	Armenia
Kirgizia		Azerbaidzhan
Latvia		Georgia
Uzbekistan		Kazakhstan
Moldavia		Lithuania
Ukraine		Tadzhikistan
		Turkmenistan
		Russian Republic

[1]Constructed using sebestoimost' data reported in tables 3 and 4. Groupings determined by the number of commodity production cost figures greater or less than sample mean for that commodity. Extra weight is given to relatively low cost production of commodities whose proportion of nationwide production exceeds the republic's contribution to gross agricultural production, referred to in this paper as specialization.

Table 6--Republics ranked by estimated relative technical efficiency

Rank	Republic	Average one-sided error	Percentage of best practice or frontier
			Percent
1	Lithuania	0.04393	95.7
2	Moldavia	.04685	95.4
3	Georgia	.05670	94.5
4	Russian Republic	.05939	94.2
5	Latvia	.06036	94.1
6	Estonia	.06101	94.1
7	Armenia	.06563	93.6
8	Belorussia	.06644	93.6
9	Ukraine	.07095	93.2
10	Uzbekistan	.07883	92.4
11	Tadzhikistan	.07885	92.4
12	Azerbaidzhan	.08201	92.1
13	Turkmenistan	.08220	92.1
14	Kirgizia	.08769	91.6
15	Kazakhstan	.08896	91.5
	Total USSR	.06794	93.4

Though the rankings list the RSFSR surprisingly high, and the Ukraine unexpectedly low, the rest of the rankings are about as expected. The ranking in table 6 is based on point estimates, and interval estimates would likely blur some of the distinctions. Still, the results do seem to break the republics into some identifiable groupings, particularly regarding a relatively efficient north and west versus a relatively inefficient south. Further, geographic categorization finds the Baltics as most efficient, followed by the RSFSR, the Transcaucasia except Azerbaidzhan, Belorussia, and the Ukraine, and finally central Asia.

The efficiency figures reported in table 6 suggest that, on average, over the sample period, Lithuania's output level was 96 percent of best possible practice, while Kazakhstan attained 92 percent. On average for the Soviet Union as a whole, the efficiency level was 93.4 percent. There was, however, significant variation in the level of technical efficiency overtime, even in relatively efficient republics. Lithuania experienced a year where the level of technical inefficiency reached 12 percent. Azerbaidzhan and Turkmenistan both had years of more than 20-percent inefficiency, but Azerbaidzhan settled down to relatively efficient operation between 1975 and 1984. Kazakhstan was very inefficient in 1965, settled down to relatively efficient levels during 1967-73, and in 1974 started fluctuating widely between extreme inefficiency of nearly 20 percent and average levels of inefficiency at 6-7 percent.

Output Losses Over Time

Total output losses due to the estimated technical efficiency suffered by Soviet agriculture over the sample period amounts to 65.1 million 1965 rubles. An annual comparison of estimated frontier output to actual output is found in figure 1. Actual output comes closest to frontier output in the good weather years of 1973 and 1978, where ideal conditions offset part of the usual inefficiency. Actual output is furthest from the frontier in the bad weather years of 1975, 1979, and 1981, where bad conditions compounded the usual inefficiencies. On average, Soviet agriculture is estimated to have lost 6.3 million rubles annually because of technical inefficiency, with the greatest 1-year loss of nearly 10 million rubles in 1981 and the smallest loss of 2.8 million rubles in 1973.

Characteristics of Efficient versus Inefficient Republics

In this section, patterns are identified in output production and input usage that may be associated with efficient versus inefficient regions. These patterns may be useful inexplaining why some regions are more technically efficient than others. First, however, an overview of the structure of agricultural

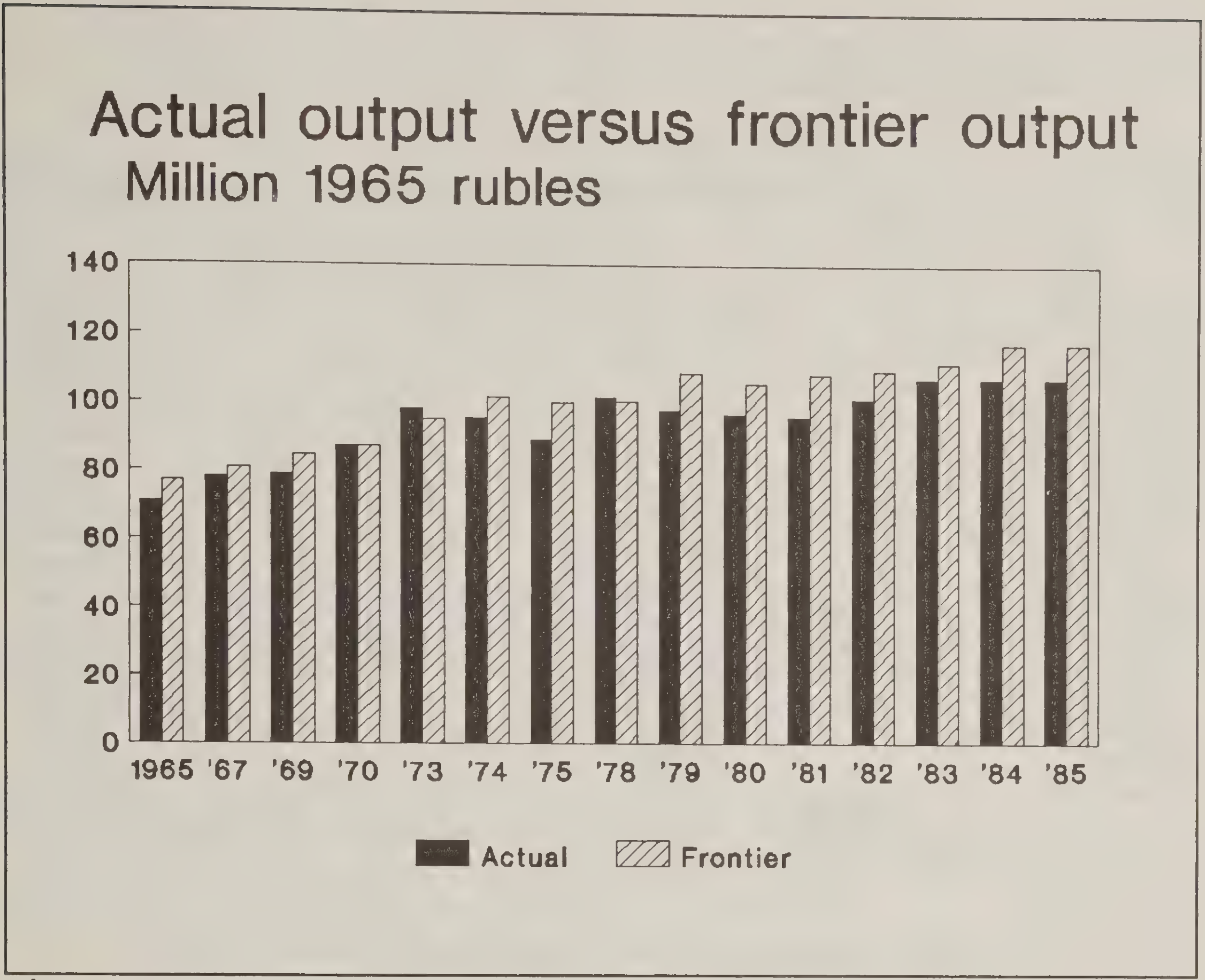

Figure 1

production in each republic is presented in tables 7-10. Table 7 shows that by far the two largest producers are the Russian Republic and the Ukraine, accounting for 69 percent of the total value of production. Kazakhstan, Belorussia, and Uzbekistan account for another 17 percent, while the remaining 10 republics account for 14 percent. Livestock products make up a majority of total production, mostly because of the Russian Republic's predominance. If we exclude the Russian Republic, total production is split evenly between livestock and crops. Republics other than the Russian Republic with greater than 60 percent of total production value derived from livestock are Lithuania, Latvia, and Estonia. On the other hand, Uzbekistan, Georgia, Azerbaidzhan, Moldavia, Tadzhikistan, and Turkmenistan all derive more than 60 percent of the total value of production from crops.

Tables 9 and 10 show the structure of commodity production in terms of volume. The Russian Republic is the dominant producer in all categories except cotton, sugarbeets, and oilseeds. Uzbekistan produces the largest share of cotton, and all cotton is grown in central Asia and the Transcaucasia. The Ukraine is the dominant producer of sugarbeets and oilseeds, with the

Table 7--Gross agricultural production by Soviet republics, 1976-80 average

Region	Gross agricultural production	Crops	Livestock
	Millions of 1973 rubles		
USSR total	123,779	56,748	67,031
Russian Republic	57,072	22,747	34,325
Ukraine	28,527	13,584	14,943
Belorussia	6,571	2,867	3,704
Uzbekistan	6,213	4,571	1,642
Kazakhstan	8,459	3,783	4,676
Georgia	1,990	1,401	589
Azerbaidzhan	2,036	1,395	641
Lithuania	2,590	846	1,744
Moldavia	2,789	1,855	934
Latvia	1,601	494	1,107
Kirgizia	1,449	673	773
Tadzhikistan	1,376	958	418
Turkmenistan	1,250	840	410
Estonia	1,080	333	747
Armenia	779	401	378

Source: Narodnoe khozyaistvo v 1980.

Table 8--Production characteristics of Soviet republics ranked by estimated technical efficiency

Estimated efficiency rank	Republic	Category of specialization[1]
1	Lithuania	Livestock
2	Moldavia	Crops
3	Georgia	Crops
4	Russian Republic	Livestock
5	Latvia	Livestock
6	Estonia	Livestock
7	Armenia	None
8	Belorussia	None
9	Ukraine	None
1	Uzbekistan	Cops, cotton
1	Tadzhikistan	Crops, cotton
12	Azerbaidzhan	Crops, cotton
13	Turkmenistan	Crops, cotton
14	Kirgizia	None
15	Kazakhstan	None

[1]Specialization in production is defined as greater than 60 percent of the total value of gross agricultural production in that category.

Table 9--Structure of crop production by Soviet republics, 1980

Republic	Total grains	Cotton	Sugar beets	Oil-seeds	Potatoes	Vegetables
			Million tons			
USSR total	189.09	9.10	79.56	4.65	67.02	25.88
Russian Republic	105.12	-	24.22	.01	36.97	10.32
Ukraine	38.10	-	47.20	2.27	13.13	6.70
Belorussia	5.01	-	1.12	-	9.33	.68
Uzbekistan	2.52	5.58	-	-	.24	2.43
Kazakhstan	27.51	.36	2.22	.10	2.24	1.10
Georgia	.64	-	.13	.01	.39	.53
Azerbaidzhan	1.14	.75	-	-	.17	.80
Lithuania	1.93	-	.53	-	1.18	.25
Moldavia	2.82	-	2.84	.25	.31	1.30
Latvia	1.05	-	.19	-	1.20	.18
Kirgizia	1.31	.21	.95	-	.29	.39
Tadzhikistan	.25	1.01	-	-	.15	.38
Armenia	.24	-	.13	-	.25	.46
Turkmenistan	.28	1.18	-	-	.01	.27
Estonia	1.20	-	-	-	1.15	.11

- Indicates little or no production in republic.
Source: Narodnoe khozyaistvo v 1980, except cotton numbers which where taken from the various 1987 republic yearbooks.

Table 10--Structure of livestock production by Soviet republics, 1980

Region	Meat	Milk	Eggs	Wool
	-- Million tons --		Millions	Million tons
USSR total	14.98	90.63	67.83	461.2
Russian Rep	7.39	46.51	39.54	212.2
Ukraine	3.46	21.11	14.51	27.2
Belorussia	.87	6.16	3.03	1.1
Uzbekistan	.32	2.27	1.46	28.5
Kazakhstan	1.06	4.47	3.37	111.4
Georgia	.14	.66	.64	6.0
Azerbaidzhan	.14	.80	.72	10.7
Lithuania	.42	2.52	.95	0.1
Moldavia	.27	1.19	.88	2.7
Latvia	.29	1.70	.73	0.4
Kirgizia	.16	.68	.41	34.1
Tadzhikistan	.09	.49	.33	5.7
Armenia	.09	.48	.47	4.7
Turkmenistan	.08	.31	.26	16.0
Estonia	.20	1.18	.54	0.4

Source: Narodnoe khozyaistvo v 1980.

Russian Republic the second largest producer of these two commodities.

Comparing table 6 with tables 7 and 8 indicates a pattern. The top six republics, in efficiency terms, are dominant producers of either crops or livestock products (see table 8). Of the remaining nine Republics, five show no dominance in either category of production and four show dominance in crop production. These four republics (Uzbekistan, Tadzhikistan, Azerbaidzhan, and Turkmenistan) all derive a large percentage of their gross agricultural production from cotton. These four republics' total value of crop production was 7,080 million rubles in 1976, 60 percent of which were state payments for cotton. The range goes from 82 percent for Uzbekistan to 38 percent for Azerbaidzhan. In a study of the technical efficiency of Soviet cotton production, Koopman (1987) estimated the average level technical efficiency of cotton production at 88.3 percent, somewhat lower than the average estimated for all agricultural production in this study. The rankings in table 6 suggest that relatively efficient republics are characterized by some specialization in production, while relatively inefficient republics either are not specialized or are specialized in cotton production.

In addition to identifying patterns on the output side associated with relative technical efficiency, one can also look at the input side. It is with respect to input usage that the strongest patterns emerge, because technical efficiency is really a measure of output produced per inputs used.

Table 11 identifies characteristics of relatively efficient republics with respect to input use. Not unexpectedly, the relatively efficient republics have greater-than-average output per input ratio. They also have greater input-per-input ratios, except for labor inputs per hectare. Thus, efficient republics seem to supply more capital inputs per labor input, use less labor per hectare, and produce more output per unit of input. While the finding of greater-than-average output per unit of input seems only reasonable when talking about relative technical efficiency, the findings of more capital inputs per unit of labor and less labor per hectare effectively describe the relatively technically efficient technology of Soviet agriculture. Republics that wander too far from the efficient combinations of inputs seem to pay a price through producing less output per unit of input. The southern republics tend to violate the estimated underlying technology the most; they tend to overuse labor and underutilize capital, despite sizable absolute production. These findings are not necessarily in conflict with the suggestion by Soviet and western authors that the southern republics hold the greatest potential for increased production. The findings, if accurately representing the state of the world, do indicate that if efficient use is to be made of the southern republic's potential, care should be given to developing the region with an efficient input mix.

Table 11--Data ratios ranked by efficiency

Republic	Output per hectare	Output per labor hour	Output per machine	Output kilo of fertilizer
USSR total	952.29	3.06	234.71	160.19
Lithuania	816.76	5.06	216.20	207.39
Moldavia	1142.90	2.87	272.61	110.48
Georgia	1969.30	2.55	374.53	175.24
Russian Republic	361.42	4.24	183.25	57.76
Latvia	759.56	5.63	205.49	210.81
Estonia	883.67	7.87	201.06	227.31
Armenia	1288.50	2.75	241.47	141.79
Belorussia	807.51	3.79	261.66	223.95
Ukraine	649.62	3.57	265.86	100.13
Uzbekistan	1157.20	2.58	242.90	232.75
Tadzhikistan	1251.40	2.48	250.51	210.31
Azerbaidzhan	1124.30	2.69	256.13	117.83
Turkmenistan	1064.30	2.46	208.32	231.85
Kirgizia	836.26	2.84	219.26	140.09
Kazakhstan	171.70	4.43	121.35	15.11

	Machinery per hectare	Labor hours per hectare	Fertilizer per hectare	Machinery per labor hour
USSR total	4.17	310.98	160.19	0.013
Lithuania	4.31	161.38	207.39	.027
Moldavia	4.86	398.73	110.48	.012
Georgia	5.39	772.20	175.24	.007
Russian Republic	2.20	85.20	57.76	.025
Latvia	4.21	134.94	210.81	.031
Estonia	4.95	112.24	227.31	.044
Armenia	5.40	467.29	141.79	.012
Belorussia	3.46	212.92	223.95	.016
Ukraine	2.71	181.81	100.13	.015
Uzbekistan	4.87	449.09	232.75	.011
Tadzhikistan	5.20	505.35	210.31	.010
Azerbaidzhan	4.33	418.63	117.83	.010
Turkmenistan	5.17	431.62	231.85	.012
Kirgizia	3.98	294.58	140.09	.014
Kazakhstan	1.46	38.77	15.11	.038

For the southern republics to achieve the estimated efficient input mix, more capital per unit of labor and less labor per hectare are required. Any combination of increasing the capital stock relative to labor inputs could accomplish this mix. Table 12 shows that while the growth rate of capital in the relatively inefficient republics has exceeded the rate of growth of labor inputs, the differential growth between the two inputs is much smaller than the average for the whole country. In fact, the relatively efficient republics tend to have stable or declining labor use over time, while the inefficient republics continue to use increasing amounts of labor. Excessive labor use, especially in Soviet central Asia, has been widely criticized in the Soviet press as inefficient use of resources. The above analysis appears to confirm this criticism. The implications of these findings are that if the southern republics are to be developed efficiently, consideration must be given to reducing labor inputs to get the most economic effect out of the increased capital inputs.

Comparisons with Other Studies of Technical Efficiency

Danilin and others applied stochastic frontier methodology to the Soviet cotton-ginning industry. Their findings suggest that the ginning industry was relatively efficient overall, compared with

Table 12--Input growth ranked by efficiency, 1964-85

Republic	Growth of labor hours (a)	Growth of machinery (b)	Spread in input growth rates (b)-(a)
USSR total	-.8	7.9	8.7
Lithuania	-1.9	9.4	11.3
Moldavia	-.5	10.3	10.8
Georgia	.5	6.9	6.4
Russian Republic	-1.6	8.0	9.6
Latvia	-2.0	9.4	11.4
Estonia	-2.6	9.4	12.0
Armenia	.5	5.8	5.3
Belorussia	-2.0	9.1	11.1
Ukraine	-1.7	8.1	9.8
Uzbekistan	3.4	6.9	3.5
Tadzhikistan	3.4	7.3	3.9
Azerbaidzhan	2.7	6.9	4.2
Turkmenistan	4.8	7.1	2.3
Kirgizia	2.9	6.3	3.4
Kazakhstan	.7	7.9	5.3

best practice with a 7-percent mean level of technical inefficiency, and that random environmental variation accounted for three times more total variation than variation due to technical inefficiency.

At this juncture, it is worth reiterating that none of these studies can comment on absolute technical efficiency as measured by engineering standards or economic efficiency. The Danilin study points out that their 93-percent measure of average technical efficiency against best practice is difficult to compare with true engineering potential or to international levels of efficiency achieved by other cotton-ginning countries because such estimates do not exist. They do, however, go on to say that, "the high mean and small variance of technical efficiency estimates is an important finding, one that reveals that traditional Soviet methods may well be more effective in controlling efficiency than is usually supposed" (Danilin and others, p. 231).

While the results presented in this or Danilin and others' study do not absolutely indicate a high or low level of technical efficiency, one can gain some international perspective by comparing these results with other studies that have used frontier methodology to measure technical efficiency.

Timmer used a linear programming model for a deterministic, as opposed to stochastic, frontier model on U.S. agriculture for the 48 contiguous States, 1960-67. Even with a finer level of geographic differentiation, Timmer's efficiency ratings ranged from 99.1 to 81.0 percent with an average level of technical efficiency of 92.3 percent.

Aigner, Lovell, and Schmidt reestimated Timmer's model using frontier methodology with a truncated exponential distribution assumed for the inefficiency component. They found an average level of technical efficiency of nearly 99 percent, and the contribution of the one-sided error variance to total variance to be less than 0.5 percent.

Comparing this study with Timmer's and Aigner, Lovell, and Schmidt's on the United States is not a valid comparison of international differences in technical efficiency because of differences in the models. Still, some weak comparative statements seem in order. First, Timmer's deterministic frontier approach does not allow for stochastic shocks to the core production frontier, but the finer geographic breakout could more precisely differentiate efficient from inefficient regions. Both this study and Timmer's put average efficiency levels within 10 percent of the frontier. The Aigner, Lovell, and Schmidt study suggests that the additional assumption of a stochastic frontier greatly improves the average level of efficiency for U.S. agriculture. They provide only summary information, so no State-

by-State comparison with the later comparative section of this study will be possible.

A direct comparison of the Aigner study and the results of this study weakly suggests that the Soviet Union is relatively inefficient, with output variation coming largely from variation in technical efficiency. Very little output variation in the United States comes from technical inefficiency.

Some other international comparisons are possible using western studies. These comparisons involve independent studies focusing on diverse industries that use differing methodologies and assumptions. But the results should provide additional perspective on the range of results for stochastic frontier estimators.

Aigner, Lovell, and Schmidt also provided an empirical illustration using the U.S. primary metals industries. The estimated symmetric component of the error term far exceeded the estimated one-sided component table 13. Aigner, Lovell, and Schmidt suggest that the results show substantial variation of the frontier across States, but relatively little variation of observed output beneath the frontier. Schmidt and Sickles found substantially different results for U.S. airlines. Their study suggests variation due to technical inefficiency is much greater than variation due to random environmental effects. Schmidt and Lovell looked at U.S. steam electric-generating plants and concluded that, again, technical efficiency accounted for most of the total variance, and that the mean level of operating efficiency was 90 percent of best practice. Greene's study of U.S. manufacturing found similar results, but with a higher mean relative efficiency.

Koopman's study of Soviet cotton-growing found technical efficiency levels on the same magnitude as did this current study. The average efficiency level was about 88 percent, but the percentage of total output variation due to technical inefficiency was nearly three times the level of the random component, larger than what was found in this study. In this study, the cotton-growing republics are inefficient compared with the other Soviet republics, and even with a completely different data set, their efficiency measures are on the same order of magnitude. The consistency of the studies is somewhat reassuring.

To summarize, in the 13 studies presented in table 12, there is a wide range of results, particularly for λ, indicating that the contribution of technical inefficiency to output variation differs greatly from study to study. Furthermore, the estimated mean level of technical inefficiency varies from less than 1

Table 13--Estimates of technical efficiency

Country	Author	Sector	Time period	Efficiency estimates	λ[1]
USSR	Current study	Agriculture	1964-85	0.93	1.75
USSR	Danilin and others	Cotton ginning	1974	.93	.54
USSR	Koopman	Cotton growing	1960-84	.88	2.74
USA	Timmer[2]	Agriculture	1960-67	.92	*
USA	Aigner and others	Agriculture	1960-67	.99	.073
Sweden	van den Broeck and others	Dairy plants	1964-73	.89	*
USA	Green	Manufacturing plants	1974-81	.98	*
USA	Schmidt and Sickles	Airlines	1970-78[3]	.87	12.42
Brazil	Lee and Tyler	Industry	1971	.621	.006
Indonesia	Pitt and Lee	Weaving industry	1972-73, 1975	.67	.71
Colombia	Tyler and Lee	Apparel manuf.	1974	.55	2.98
		Food products	do.	.641	.48
		Footwear	do.	.563	.55
		Furniture	do.	.98	.001
		Metal products	do.	.99	.001
France	Meeusen and van den Broeck	Glass products	1962	.94	.096
		Milk products	do.	.93	.099
		Textiles	do.	.91	.104
		Machine const.	do.	.90	.127
		Electrical mach.	do.	.86	.181
		Vehicles	do.	.83	.248
		Industrial chem.	do.	.79	.276
		Paper	do.	.79	.321
		Footwear	do.	.76	.529
		Sugar/distillery	do.	.71	.434
USA	Schmidt and Lovell	Steam-electric plants	unknown	.90	2.81

* = Not estimable from data reported.
[1]See page 15 for definition of λ.
[2]Used a deterministic frontier (linear programming), not a stochastic frontier.
[3]Data used are quarterly.

percent in U.S. agriculture to a high of 45 percent in Colombian apparel manufacturing.

The three studies using Soviet data fall in the middle of the ranges presented. These wide-ranging results and the difficulty in making comparisons over nonhomogeneous studies suggest that a model designed for comparative work is necessary to compare the relative efficiency of the western and Soviet economies. In the next section, results for just such a comparative model are presented.

Comparative Estimates of Agricultural Technical Efficiency

In this section, data collected by Karen McConnell Brooks for her study on the relative technical efficiency of the 15 Soviet Republics, 10 U.S. States, 4 Canadian Provinces, and Finland is used for a comparative analysis between Soviet and non-Soviet agriculture. Brooks finds that "total factor productivity in the non-Soviet sample is between one-and-a-half and twice that of the USSR." However, to use differences in total factor productivity (TFP) as a measure of differences in technical efficiency, one must assume that the Soviet and non-Soviet areas in the sample share the same technology and that their relative locations in production space represent their respective levels of technical efficiency. Brooks makes the same technology assumption to draw inferences about technical efficiency based on TFP differences. Such an assumption may be overly strong. According to Nelson "at any given time one would expect to find considerable variations among firms with respect to the vintage of technology, certainly between countries, but even within a country" (Nelson, p. 1230).

Nelson's statement seems particularly true in the current case given the different levels of economic development between the Soviet and non-Soviet samples. In one aspect, though, this study may include a possible exception to Nelson's assertion about differing vintages of technology within a country. The Soviet Union's technology decisions may be considered relatively homogeneous as they are implemented to a high degree by central planners, from inception to allocation, with little regard for factor scarcities. Technology choices should be made based on factor scarcities with signals passed by market-determined prices. So given a particular endowment of resources, one country (or region of a country) may choose a lower level of technology than another and thus have a completely different production possibilities frontier, and still be technically

efficient. In our sample, there is no reason to assume similar factor scarcities between the Soviet and non-Soviet samples.[7]

The same-technology assumption fails the traditional F-test, however. So, given the different levels of economic development in the regions sampled, relative locations in production space likely reflect different levels of development rather than different levels of technical efficiency.[8]

The stochastic frontier methodology used in this study allows for separate technologies, and instead of comparing relative TFP as a measure of technical efficiency, it measures technical efficiency in the sense of how close, on average, the two subsamples come to their individual production frontiers (actually observed best-practice frontiers).

Brooks's study highlights the differences in TFP for the Soviet and non-Soviet samples. Brooks concludes that the Soviet Union is technically inefficient because TFP in the non-Soviet sample is 1.5 to 2 times greater than that of the Soviet sample, which is equivalent to saying that the Soviet Union's level of technical efficiency is 0.50 to 0.67 that of the United States. It could be, however, that the TFP differential is really more indicative of the Soviet sample's location in production space compared with the non-Soviet sample, rather than a measure of relative levels of technical efficiency. This distinction is very important because it helps to identify what may be a major source of slow growth in the Soviet-type system, slow technological change, instead of assuming that Soviet farms (or planners) are unable to combine available inputs efficiently to produce output.

---

[7]There is no reason to assume similar factor scarcities within the broad categories of Soviet and non-Soviet either, but it is perhaps reasonable to assume that factor scarcities within the non-Soviet regions are more similar within the group than to those in the Soviet sample. A similar argument could be made for the regions within the Soviet sample relative to the non-Soviet sample. Looking at table 9.8, p. 141 of Johnson and Brooks, one sees that while output per hectare is relatively homogeneous across samples, the other ratios suggest dramatically different technologies across samples but not within samples, lending some credence to the assumption of different production functions for Soviet and non-Soviet, but less need for a finer geographic breakout.

[8]Similar tests were attempted for within-sample differences, but the parameter estimates for the smaller samples were not economically meaningful. Given the discussion in footnote 7, the assumption of similar technologies within the Soviet and non-Soviet samples seems reasonable.

While this study provides am alternative way to measure technical efficiency by taking different technologies into account, and provides significantly different results than Brooks, one must recognize that substantial productivity differences likely exist, as Brooks suggests. But the reasons for those productivity differences should not be assumed to be differences in technical efficiency.

In the following section, the estimated losses to four economies due to technical inefficiency in their agricultural sectors is discussed, ignoring potential losses due to allocative inefficiency.

It is initially assumed that both Soviet and non-Soviet portions of the sample have identical technologies represented by a translog functional form. Then a pooled time-series cross-section equation is estimated and sequentially tested for different intercepts then for overall homogeneity of the parameter estimates. The results of the F-tests are F = 5.29, which is greater than F_c at the 99-percent level with degrees of freedom 2 and 574, and F = 5.38, which, again, is greater than F_c at the 99-percent level with degrees of freedom 23 and 554 (detailed empirical results are available upon request from the author). Thus, the statistical tests suggest separate technologies for the two subsamples, Soviet and non-Soviet. The results of the two estimations representing the two technologies are reported in table 14.

A brief overview of the parameter estimates shows relatively reasonable results. Other than the significantly negative coefficient on livestock in the Soviet equation and insignificant parameter estimates for machinery in both equations, all other important parameter estimates are positive and significant. The Soviet sample's parameter estimates are quite similar to those found in our earlier Soviet model (see table 2). The fact that the two models were estimated using independently constructed data sets, yet still provide very similar estimates, suggests that the Soviet estimates at least are rather robust. Further comparisons of the estimates with intercountry, cross-section studies by Bhattacharjee and Hayami and Ruttan lend further credence to the overall parameter estimates.

Of particular interest in table 14 is the estimate of λ, the ratio of the standard error of the estimate due to technical inefficiency to the standard error of the estimate due to random symmetric events. The estimates suggest that both Soviet and non-Soviet samples experience roughly equal, or statistically insignificant, variation in production due to technical inefficiency, and that variation due to technical inefficiency is twice that due to the symmetric component. As earlier, we can

Table 14--Stochastic frontier estimation results

Variable	Soviet $\hat{\beta}$	Soviet t-statistic	Non-Soviet $\hat{\beta}$	Non-Soviet t-statistic
One	0.0278	(1.14)	0.1133	(3.84)
Year	.0155	(4.11)	.0154	(4.82)
Climate	.0026	(.12)	.0192	(2.83)
Fertilizer	.2624	(4.57)	.1529	(5.20)
Livestock	-.3849	(-2.03)	.3513	(5.05)
Machinery	-.0811	(-.33)	-.0458	(-.47)
Land	.5546	(4.96)	.2089	(2.93)
Labor	.5642	(7.32)	.3992	(7.80)
Fertilizer squared	.0539	(1.72)	.0376	(2.64)
Machinery squared	-.0918	(-.48)	.0269	(.38)
Land squared	.3111	(3.75)	-.0602	(-1.07)
Labor squared	-.1215	(-1.32)	-.0556	(-1.23)
Livestock squared	.0211	(.85)	.2842	(2.57)
Fertilizer*machinery	-.0417	(-.30)	.1134	(2.60)
Fertilizer*land	.0357	(.46)	-.0844	(-2.19)
Fertilizer*labor	-.2633	(-3.49)	-.0109	(-.29)
Fertilizer*livestock	.1478	(1.19)	-.1029	(-1.59)
Machinery*land	-.0388	(-.24)	.0303	(.32)
Machinery*labor	.4687	(1.82)	.0839	(1.24)
Machinery*livestock	-.2288	(-.75)	-.4184	(-1.88)
Land*livestock	-.6406	(-2.64)	.0138	(.12)
Land*labor	-.2450	(-1.77)	.1126	(1.92)
Livestock*labor	.5136	(1.64)	-.0725	(-.64)
$\hat{\lambda}$	2.0394	(4.29)	1.9024	(4.51)
$\hat{\sigma}$	.1094	(17.00)	.1290	(16.74)

Statistics from GLS regressions:

Soviet	non-Soviet
n = 299	n = 299
R^2adj = .9800	R^2adj = .9791
DW = 1.911	DW = 1.931
SSR = 1.7564	SSR = 2.5141
SER = .07977	SER = .09544

use the estimates of λ to estimate the mean level of technical inefficiency (u) for both samples. The mean level of technical inefficiency for the Soviet sample is 7.7 percent and for the non-Soviet sample is 8.9 percent table 15.

The overall level of technical efficiency for the Soviet sample is 92.6 percent, so on average for the entire sample in any given year, production is 7.4 percent below what could be attained if producers had been on the best practice frontier. The corresponding efficiency level for the non-Soviet sample is 91.5 percent. The Soviet sample's estimate is very close to the one found earlier of 93.4 percent. Again, relative to findings in

Table 15--Regional rankings using estimated technical efficiencies

Region	Estimated inefficiency $\hat{u}$ [1]	Efficiency level $z=e^{(-u)}$ [2]
Soviet Georgia	0.05055	0.9507
Lithuania	.05226	.9491
Moldavia	.05449	.9470
Belorussia	.06087	.4910
Estonia	.06463	.9374
Ukraine	.06712	.9351
South Dakota	.06797	.9343
Russian Republic	.07167	.9308
Minnesota	.07362	.9290
New Mexico	.07435	.9283
Arizona	.07447	.9282
Finland	.07478	.9279
Armenia	.07568	.9271
Uzbekistan	.07578	.9270
Kirgizia	.07666	.9262
Turkmenistan	.08121	.9220
Latvia	.08126	.9216
Colorado	.08185	.9214
Ontario	.08398	.9195
Manitoba	.08505	.9185
Nevada	.08721	.9165
North Dakota	.09426	.9100
Utah	.09574	.9087
Kazakhstan	.09735	.9072
Nebraska	.10260	.9025
Alberta	.10435	.9009
Tadzhikistan	.11317	.8930
Montana	.11466	.8917
Saskatchewan	.12623	.8814
Azerbaidzhan	.13748	.8715
USSR mean	.077	.926
Non-USSR mean	.089	.915

[1] See Jondrow, Lovell, Materov, and Schmidt, 1982.
[2] See Danilin, Materov, Rosefielde, and Lovell,1985.

other studies using this methodology, applied mostly on industry, these levels of efficiency appear reasonable. The result least expected is the estimated relative equality in technical efficiency between the Soviet and non-Soviet portions of the sample. The estimated efficiency differential is only 1 percent and is in favor of the Soviet Union.

It is worth noting that while the regions sampled attempt to control for climatic differences, they do so only imperfectly. Should climate not be controlled for and the sample expanded to all U.S. States and other "efficient" western producers the relative average efficiency levels might change significantly. One finding of interest is the dispersion of the Soviet sample relative to the non-Soviet sample (see table 15). The Soviet Union has the 5 most efficient estimates of efficiency, 7 of the

top 110, but also has by far the region with the lowest estimated level of efficiency. The range between most and least efficient in the Soviet sample is 8 percentage points, but in the non-Soviet sample the range is only 5.3 percentage points, and for the 10 U.S. States alone the range is only 4.2 percentage points. This might suggest that central planners are not as effective in maintaining a consistent level of efficiency across regions as is the market in the non-Soviet portion of the sample.

For the Soviet portion of the sample, the Baltic republics tend to be the most efficient, while the republics of central Asia are the least efficient. The relative rankings of the Soviet republics alone are consistent with the rankings found in the earlier section, using the data set for the Soviet Union alone. Of 15 republics, 12 have relative rankings that differ by less than three places, 2 differ by four places, and 1, Latvia, differs by seven places.

One can look for identifying characteristics of efficient versus inefficient regions in terms of output and input use. In the Soviet case, the same kinds of patterns emerge as in tables 11 and 12. Relatively efficient republics use more capital per labor input and less labor per hectare than inefficient ones. Labor inputs tend to decline while capital inputs increase in efficient republics, while both inputs grow in the inefficient republics.

In the non-Soviet case, no strong identifying patterns emerge from relative input use or growth rates. One reason for that may be that substantial growth in the non-Soviet sample is derived from sources other than just input growth. This being the case, causes of differences in efficiency are not likely to be observable in the data. For instance, as stated earlier, differences in the ability of managers and workers to combine inputs into output is in an example of one source of technical inefficiency. In the Soviet case, it is obvious from the data that the southern republics are not as effective at combining inputs to produce output, as evidenced by their excessive labor usage. The data show no such patterns for the non-Soviet sample, and here it may show differences in how regions are affected by or respond to the varying policy environments and changing technologies over time, rather than differences in input mixes.

For the non-Soviet portion of the sample, the United States has the four most efficient regions, the States of South Dakota, Minnesota, New Mexico, and Arizona. Timmer, in the only other detailed study on agriculture using a frontier approach (though deterministic, not stochastic) on the 48 contiguous United States, found a similar average efficiency level. Timmer also found South Dakota to be the most efficient State but had rather different relative rankings for the remaining States in this study's sample. Timmer's data were substantially different than

the data used here. They were mostly financial, which may be more appropriate for market-oriented economies as they capture variables in terms that might more accurately reflect inputs used. Timmer's data also covered a much shorter time period, 1960-67. Aigner, Lovell, and Schmidt used Timmer's data in a stochastic frontier model and found a higher level of technical efficiency than Timmer did.

For the other regions in the non-Soviet sample, Finland ranked 5th, 12th overall in the combined sample, with an efficiency ranking roughly equal to Soviet Armenia. The four Canadian provinces had the lowest average efficiency level, 1.2 percent below the United States, and nearly 2.3 percent below Finland. The fact that the Soviet sample fits as tightly to its best practice frontier as the non-Soviet sample implies something about the ability of central planners to discipline producers to perform at a reasonable level of efficiency relative to the best existing observable practice in the country. Danilin and others reached a similar conclusion regarding Soviet cotton ginning.

If these results are representative of the true state of the world, then it appears that the lack of bankruptcy discipline, planners' interference in day-to-day operations, wage and bonus systems, and other such factors may have little effect on the technical efficiency of Soviet farming compared with that of the non-Soviet regions sampled here. Perhaps planners are relatively effective at efficiently implementing technical operations, even if the pace of this implementation is slow, or the allocative aspects are economically incorrect. In fact, one could argue that the Soviet agricultural economic policy environment is relatively static, as many prices are fixed for long periods of time, machinery models and other sources of technological improvements are changed only infrequently, planners' preferences remain stable, and macroeconomic factors seldom fluctuate. This static environment may allow farmers and planners to know where the production possibilities frontier is for this particular technology and to provide a relatively stable environment in which to reach the frontier.

Government intervention in the non-Soviet regions sampled here maybe as detrimental to technical efficiency as the Soviet Government's intervention. Another possible explanation is that while slow technological change and policy stability in the Soviet sample allows planners and farmers to be somewhat technically efficient in the static sense, the non-Soviet sample may face technology and policy changes so rapid that some farms are always off the frontier. The Soviet stability may cost them in terms of dynamic efficiency (growth), while the non-Soviet sample may incur equal or higher static inefficiency costs but greater dynamic efficiency and growth.

Most observations on differences in total factor productivity (Johnson and Brooks, and see table 15) and production growth associated with the time trend suggest that the non-Soviet sample has grown faster than the Soviet sample. The conclusion that follows would be that while the levels of technical efficiency are nearly the same, one system is more effective at growth. This finding is important because it suggests that perhaps the biggest drawbacks to central planning are the impediments to innovation and technological change.

Hayami and Ruttan's Theory of Induced Development in the Soviet Context

Hayami and Ruttan have described what they feel to be critical elements necessary for continuous innovation and technological changes and to translate those changes into economic growth. Hayami and Ruttan's theory of induced development identifies four critical elements for agricultural growth and economic development: (a) induced innovation in the private sector, (b) induced innovation in the public sector, (c) interaction between technical change and institutional development, and (d) dynamic sequences of technical change and growth. Hayami and Ruttan also specify that the term "innovation" is used in the broad context of improvements in science, technology, industrial management, and economic organization. Hayami and Ruttan argue, and this author agrees, that these elements are necessary for sustained, efficient, agricultural growth, which in turn, can be translated into national economic growth. The application of this theory to the Soviet context is perhaps most interesting as a case where these elements in effect do not exist, with the consequences thereof apparent in the slow growth of recent years.

Soviet agricultural growth in recent years has slowed measurably, and estimates of TFP growth indicate that the growth that has occurred has been costly (table 16). The previous sections of this paper presented some partial empirical evidence on the allocative and technical efficiency of the Soviet Union relative to a number of western countries. While the evidence is not completely convincing, what seems most striking is the lack of clear dominance in static efficiency in the West's favor, despite substantially better economic performance over the past 15 years. It was suggested that the relative stability of economic forces and policies might allow the Soviets to attain a level of static economic efficiency comparable with the West's. But the opportunity cost to the Soviet Union has been long-term growth.

The evidence on static efficiency and growth presented earlier suggests that the Soviets have a tendency to move out along a given production function by adding more and more resources rather than shifting the production function out over time by changing technology. Such a tendency would seem logical for the

Table 16--Estimates of total factor productivity growth in agriculture for selected countries

Country	Author	Period	Rate
United States	Ball	1960-79	1.69
Canada	Brinkman and Prentice	1962-80	1.39
USSR	Wong	1960-80	-1.69
Hungary	Wong	1960-80	-.19
Poland	Wong	1960-80	-3.35
Bulgaria	Wong	1960-80	-.90
German Democratic Republic	Wong	1960-80	.83
Czechoslovakia	Wong	1960-80	.17
Romania	Wong	1960-80	-1.67
Yugoslavia	Wong	1960-80	-.86

planned Soviet system since planning is likely easier given known technologies. And the planning process, which is material balance planning, would eliminate the need to plan for innovations and incorporating innovations not yet known into the plan.[9] This is but one of the incentives not to innovate in the Soviet system.

Another trademark of a Soviet-type economy is artificially set, relatively stable prices. In the context of Hayami and Ruttan's theory, this condition would play a particularly important role in preventing economic growth through innovation. Hayami and Ruttan and others argue that swings in relative factor prices reflect new scarcity conditions, which bring about most innovations. Innovations are introduced because economic agents have incentives to conserve on the use of the now higher cost factor(s). In the Soviet case, prices are not necessarily set to reflect relative scarcity, and prices are seldom changed. In addition, economic agents do not necessarily respond to a price

[9]See Gregory and Stuart, pp. 135-40, for an overview of material balance planning.

change because profit maximization or cost minimization may not be their objective function, and planners interfere in many operating decisions. These factors all contribute to break down the effects of a main instigating force behind innovation.

Returning to the four critical elements underpinning the theory of induced development, we find the Soviet Union apparently deficient in all four elements. The need for induced innovation in the private sector is completely lacking because there is no significant legal private sector. There are very strict regulations on the size and profitability of legal private activities, all of which keep an individual enterprise very small and the sector, as a whole, unorganized as a major economic force. Innovation in the private sector of the Soviet Union as it stands in 1988 is not likely to be a major source of economic growth.

Innovation in the public sector is where the Soviet Union anticipated substantial success because of its emphasis on centralized decisionmaking. But as Berliner has documented, impediments to innovation in the USSR are significant (see Berliner, both citations). In addition to the inability to plan for innovations and their introduction, other impediments include an input allocation system that does not depend on prices and is not flexible, and planner and managerial incentive systems that discourage innovation. Because the input supply system is rigid, securing stable sources of supply is very important to Soviet managers, and the cost of establishing stable supplies is not important because profitability is not a key indicator of success, only the amount of output produced. Innovation that requires new inputs is disruptive, and hence unlikely to be implemented willingly if it interrupts production and increases the uncertainty of input needs. One study indicates that while the United States and West Germany implement more than half of their inventions in little more than 1 year, the Soviets require 3 years (Martens and Young, pp. 472-509).

The lack of interaction between technical change and institutional development is less well established for the Soviet case. Basically, this element argues that not only do the public and private sectors respond to the need for innovation, but research institutions do also. To quote Hayami and Ruttan (p. 61), "changes in market prices and technological opportunities introduce disequilibrium in existing institutional arrangements by creating profitable new opportunities for institutional innovations." Clearly, the necessary market forces are missing from the Soviet environment, but other impediments that might exist have not been widely identified although political pressures and infighting could likely be sources of further impediments. Even without other contributing factors, the lack of market signals seems enough to prevent institutional innovation in the Soviet case.

The inflexibility of the Soviet input supply sector, as well as the bias against innovation in most economic agents' objective functions will likely impede the final critical element, dynamic sequences of technical change and growth. This element argues that one innovation leads to a new disequilibrium and further need for new innovations within and across sectors. Additionally, the Soviet economy has been divided into a number of ministries and subministries, each with specific goals and objective functions. There is little reward for coordination of interbranch activities in the short term, let alone a continuing path coordination in the long term. Bureaucratic favoritism and political positioning are quite likely to have as much effect on decisions as are economic arguments.

In sum, all four critical elements for the theory of induced development are to some degree impeded in the Soviet case. This may provide an explanation for the Soviet Union's relatively poor dynamic economic performance in recent years despite relatively good static efficiency measures. If these conclusions are correct, what the Soviet Union might need to improve economic performance is more flexibility and incentives to innovate, rather than improvements in a system that is statically efficient in the allocation and use of resources but causes dynamic inefficiency by inhibiting innovation and change.

Conclusions

This paper has presented evidence on the comparative static efficiency of Soviet agriculture, compared with that of the United States, Canada, and Finland. Previous studies on allocative efficiency have not shown significant differences in the efficiency of Soviet and non-Soviet samples. Previous evidence gathered on technical efficiency had suggested that the Soviet Union was relatively technically inefficient in the static sense. This study argues that this previous work was relying on differences in TFP, and that differences in TFP reflect only differences in technical efficiency under very restrictive conditions that are unlikely to hold. Using a stochastic frontier methodology, this study found that the Soviet Union operated at 93.4 percent of its observed best-practice production frontier. Technical efficiency was estimated by republic, and the Baltics were found to be most efficient, followed by the Russian republic, the Transcaucasia (except Azerbaidzhan), Belorussia, the Ukraine, and finally the central Asian republics were least efficient. The overall and regional efficiency findings could have important implications for future agricultural development policy in the Soviet Union. Heavy investment, without regard for efficient input mix, in regions estimated to be relatively inefficient will cause only more costly growth. This study's findings indicate that further

infusions of capital into the southern regions of the country must be accompanied by a release of labor from the agricultural sector, or production will continue to be relatively inefficient and, hence, more costly than necessary compared with the northern republics.

The current study was unable to show significant differences in the technical efficiency of Soviet, U.S., Canadian, and Finnish agriculture. Despite indications of no significant differences in allocative or technical efficiency between Soviet and western economies, there is no doubt that growth, especially in agriculture, has been much slower in the Soviet Union. Empirical evidence (the TFP estimates reported in table 16) indicates that Soviet output growth results mainly from input growth, with little or no technological change. In other words, Soviet growth is achieved by moving out along a given production function rather than through continued shifting out of the production function, as appears to be the case in the non-Soviet sample. Thus, while in a static sense the Soviet Union appears to be as efficient as the West, in a dynamic sense, it appears far less efficient than the West.

From Hayami and Ruttan's theory of induced development, the necessary criteria for cost-effective development and growth all appear greatly impeded in the Soviet case. This has important implications for future Soviet agricultural policy. Policy changes that do not alleviate the impediments to induced technological change and development are not likely to improve agricultural growth significantly in the long term.

References

Aigner, D.J., C.A.K. Lovell, and P.J. Schmidt, 1977. "Formulation and Estimation of Stochastic Frontier Production Models," Journal of Econometrics, (6) 1, 21-37.

Ball, V.E., 1985. "Output, Input, and Productivity Measurement in U.S. Agriculture, 1948-79," American Journal of Agricultural Economics, (67) 3, 475-86.

Barreto, H., and R.S. Whitesell, 1987. "Estimation of Output Losses from Allocative Inefficiency: A Comparison of the Soviet Union and the United States," unpublished manuscript, Williams College, Williamstown, MA.

Berliner, J., 1976. The Innovation Decision in Soviet Industry. (Cambridge, MA: MIT Press).

Berliner, J., 1976. "Prospects for Technological Change," Soviet Economy: A New Perspective. (Washington, DC: Joint Economic Committee).

Bhattacharjee, J.P., 1955. "Resource Use and Productivity in World Agriculture," Journal of Farm Economics, (37), 57-71.

Brinkman, G.L., and B.E. Prentice, 1983. Multifactor Productivity in Canadian Agriculture: An Analysis of Methodology and Performance 1960-80 (Ottawa, Canada: Agriculture Canada).

Broeck, J. van den, F.R. Forsund, L. Hjalmarsson, and W. Meeusen, 1980. "On the Estimation of Deterministic and Stochastic Frontier Production Functions: A Comparison," Journal of Econometrics, (13), 5-25.

Brown, R.S., and L.R. Christensen, 1981. "Estimating Elasticities of Substitution in a Model of Partial Static Equilibrium: An Application to U.S. Agriculture, 1947 to 1974", in E.R. Berndt and B.C. Field, Modeling and Measuring Natural Resource Substitution. (Cambridge, MA: MIT Press).

Danilin, V.I., I.S. Materov, S. Rosefielde, and C.A.K. Lovell, 1985. "Measuring Enterprise Efficiency in the Soviet Union: A Stochastic Frontier Analysis," Economica, (52) 6, 225-33.

Desai, P., 1976. "The Production Function and Technical Change in Postwar Soviet Industry: A Reexamination," American Economic Review, (66) 3, 372-81.

Desai, P., and R. Martin, 1983. "Efficiency Loss from Resource Misallocation in Soviet Industry," Quarterly Journal of Economics, (98) 3, 441-56.

Gray, K.R., and F.W. Crook, 1988. "USSR, China, and Eastern Europe," Agriculture in the Uruguay Round: Analysis of Government Support. Staff Report No. AGES-880802. Econ. Res. Ser., U.S. Dept. of Agr.

Greene, W.H., 1980. "On the Estimation of a Flexible Frontier Production Model," Journal of Econometrics, (13), 101-15.

Greene, W.H., 1986. LIMDEP, User's Manual. (New York).

Gregory, P.R., and R.C. Stuart, 1981. Soviet Economic Structure and Performance, second edition. (New York: Harper and Row).

Harberger, A.C., 1966. "Efficiency Effects of Taxes on Income from Capital," Effects of Corporation Income Tax. M. Kryzaniak ed. (Detroit, MI: Wayne State University Press).

Hayami, Y., and V. Ruttan, 1971. Agricultural Development: An International Perspective. (Baltimore and London: The Johns Hopkins Press).

Johnson, D.G., and K.M. Brooks, 1983. Prospects for Soviet Agriculture in the 1980's. (Bloomington: Indiana University Press).

Jondrow, J., C.A.K. Lovell, I.S. Materov, and P. Schmidt, 1982. "On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Model," Journal of Econometrics, (19), 233-38.

Koopman, R.B., (forthcoming). "The Technical Efficiency of Soviet Cotton Production," Communist Agriculture, Vol. 1: Farming in the Soviet Union and Eastern Europe. (London: Routledge).

Koopman, R.B., 1984. Soviet Project Choice Criteria: An Empirical Evaluation of the 1969 Reforms. Ph.D. dissertation, Boston College.

Kumbhakar, S.C., 1987a. "The Specification of Technical and Allocative Inefficiency in Stochastic Production and Profit Frontiers," Journal of Econometrics, (34), 335-48.

Kumbhakar, S.C. 1987b. "Production Frontiers and Panel Data: An Application to U.S. Class 1 Railroads," Journal of Business and Economic Statistics, (5) 2, 249-55.

Lee, L.F., and W.G. Tyler, 1978. "The Stochastic Frontier Production Function and Average Efficiency: An Empirical Analysis," Journal of Econometrics, (7), 385-89.

Lovell, C.A.K., and R.C. Sickles, 1983. "Testing Efficiency in Joint Production: A Parametric Approach," Review of Economics and Statistics, (65) 1, 51-58.

Martens, J., and J. Young, 1979. "Soviet Implementation of Domestic Inventions: First Results," Soviet Economy in a Time of Change. (Washington, DC: Joint Economic Committee).

Meeusen, W., and J. van den Broeck, 1977. "Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error," International Economic Review, (18) 2, 435-43.

Nelson, R.R., 1968. "A "Diffusion Model" of International Productivity Differences in Manufacturing Industry," American Economic Review, (58), 1219-48.

Olson, J.A., P. Schmidt, and D.M. Waldman, 1980. "A Monte Carlo Study of Estimators of Stochastic Frontier Production Functions," Journal of Econometrics, (13), 67-82.

Pitt, M.M., and L.F. Lee, 1981. "The Measurement and Sources of Technical Efficiency in the Indonesian Weaving Industry," Journal of Development Economics, (9), 43-64.

Rapawy, S., 1980. Civilian Employment in the USSR: 1950 to 1978, Bureau of the Census, U.S. Dept. of Comm.

Schmidt, P., and C.A.K. Lovell, 1979. "Estimating Technical and Allocative Efficiency Relative to Stochastic Production and Cost Frontiers," Journal of Econometrics, (9) 4, 343-66.

Schmidt, P., and C.A.K. Lovell, 1980. "Estimating Stochastic Production and Cost Frontiers when Technical and Allocative Inefficiency are Correlated," Journal of Econometrics, (13), 83-100.

Schmidt, P., and R.C. Sickles, 1984. "Production Frontiers and Panel Data," Journal of Business and Economic Statistics, (2) 4, 367-74.

Shoven, J.B., and J. Whalley, 1972. "A General Equilibrium Calculation of the Effects of Differential Taxation of Income from Capital in the United States," Journal of Public Economics, (1), 281-321.

Thornton, J., 1971. "Differential Capital Charges and Resource Allocation in Soviet Industry," Journal of Political Economy, (79) May/June, 545-61.

Timmer, C.P., 1971. "Using A Probabilistic Frontier Production Function to Measure Technical Efficiency," Journal of Political Economy, (79), 776-94.

Toda, Y., 1976. "Estimation of a Cost Function when the Cost is not Minimum: The Case of Soviet Manufacturing Industries, 1958-1971," The Review of Economics and Statistics, (58) 3, 259-68.

Toda, Y., 1986. "The Imperfections in Factor Market and the Loss of Production in Centrally Planned Industry: A General Equilibrium Calculation," unpublished manuscript, University of Florida, Gainesville.

Toda, Y., 1987. "Static Efficiency and the Change in Productivity of the Soviet Economy, 1960-84," paper presented at the AAASS meetings, Boston, MA.

Tyler, W.G., and L.F. Lee, 1979. "On Estimating Stochastic Production Functions and Average Efficiency: An Empirical Analysis with Colombian Micro Data," The Review of Economics and Statistics, (61) 3, 436-38.

U.S. Department of Agriculture, Economic Research Service, 1987. Government Intervention in Agriculture: Measurement, Evaluation, and Implications for Trade Negotiations. FAER-229.

U.S. Department of Agriculture, Economic Research Service, 1988. Estimates of Producer and Consumer Subsidies, Government Intervention in Agriculture, 1982-86. Staff Report No. AGES-880127.

Weitzman, M., 1970. "Soviet Postwar Economic Growth and Capital Labor Substitution," American Economic Review, (60), 676-92.

Whalley, J., 1976. "Thornton's Estimates of Efficiency Losses in Soviet Industry: Some Fixed Point-Method Recalculations," Journal of Political Economy, (84) 1, 153-59.

Whitesell, R.S., 1988. "Estimates of the Output Losses from Allocative Inefficiency: A Comparison of Hungary and West Germany," unpublished manuscript, Williams College, Williamstown, MA.

Wong, L.F., 1986. Agricultural Productivity in the Socialist Countries. (Boulder, CO: Westview Press).

Wyzan, M.L., 1981. "Empirical Analysis of Soviet Agricultural Production and Policy," American Journal of Agricultural Economics, (63) 3, 475-83.

Appendix

The data used are from official Soviet sources when available. In some cases, observations for missing years or incomplete series could be constructed from other available Soviet sources. See descriptions of each variable below for details. The variables used include gross agricultural output, fertilizer deliveries per hectare, total energy (mechanical and animal power) available in agriculture, sown area, and labor force in labor days. The sample covers 1965-85, excluding years 1966, 1968, 1971, 1972, 1976, and 1977. These years were excluded because one or more of the variables were not reported and could not be constructed from other sources.

Gross Agricultural Output

The gross agricultural output variable is based on 1965 prices and is reported directly as such up to 1976. From 1976 on, base-year prices are reported to be 1973. However, an index with 1970 as a base year is reported. The base-year price weights for the 1970 index are not reported, but they appear to be 1965 prices, as the 1970 index and the 1965 gross agricultural output variable move almost identically in overlapping years. Therefore, the 1970 index is used to calculate gross agricultural output, in 1965 prices, for the years 1976-85.

There are problems with the output variable used. The measure double counts agricultural products, such as grain for feed, used as inputs to other agricultural products, thus overstating true production. Second, the 1965 price weights may provide significantly different weights than current prices, and even though the output variable reflects only quantity changes, the values discussed in the results sections may be greater or smaller, depending on the price differentials.

Fertilizer

The fertilizer variable is fertilizer deliveries in kilograms of active ingredients per hectare. Obviously, the true variable of interest is fertilizer application per hectare. It is implicitly assumed that the efficiency of application is constant across republics and time relative to deliveries.

Capital Stock/Energy

Total energy availability serves as a proxy for capital services, on the assumption that movements in energy availabilities closely mirror changes in capital services used in agriculture. Other possible proxies could serve, including total tractor horsepower, total number of tractors, or basic production funds. There are probably arguments as to why one proxy is better than another, but the author chose energy availability with the idea that it

captured a wider variety of inputs providing capital services, and did so in strictly quantity terms.

Area

Sown area represents the land input, but does not include pastureland and meadows, hence assuming that to the extent these serve as livestock feed, they are of equal quality and quantity per head for all republics. Furthermore, in this study, no attempt is made to correct for land quality, an obvious drawback.

Labor

Total employment in agriculture is measured as labor days (with its attendant drawbacks), a figure officially reported in the yearbooks up to 1975. From 1975 on, a methodology similar to Rapawy's is used to move the 1975 figure up to 1985. Using labor productivity indexes and gross production indexes, one derives a measure of changes in total labor force. Where cross-checks are available, the construct is surprisingly accurate for 13 republics. Only Estonia and Georgia have discrepancies greater than 3 percent in the cross-check years. The employment variable does not include labor inputs to private agriculture, clearly understating labor inputs in those republics with a high percentage of gross agricultural production coming from the private plots.

UNITED STATES DEPARTMENT OF AGRICULTURE
ECONOMIC RESEARCH SERVICE
1301 NEW YORK AVENUE, NW.
WASHINGTON, DC 20005-4788